Models in science

Objectives

- Understand why we use models to support explanations and predictions
- Use models in explanations and predictions
- Identify the limitations of different models explicitly

ITTECF Classroom Practice – Standard 4

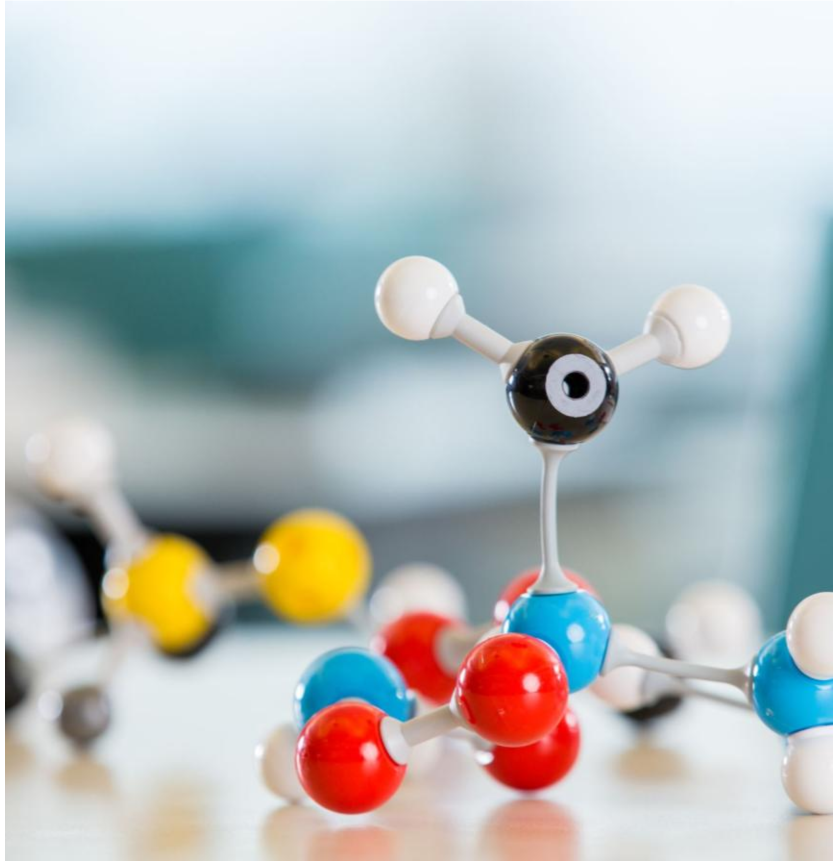
Modelling helps pupils understand new processes and ideas; good models make abstract ideas concrete and accessible.

What do we mean by models?

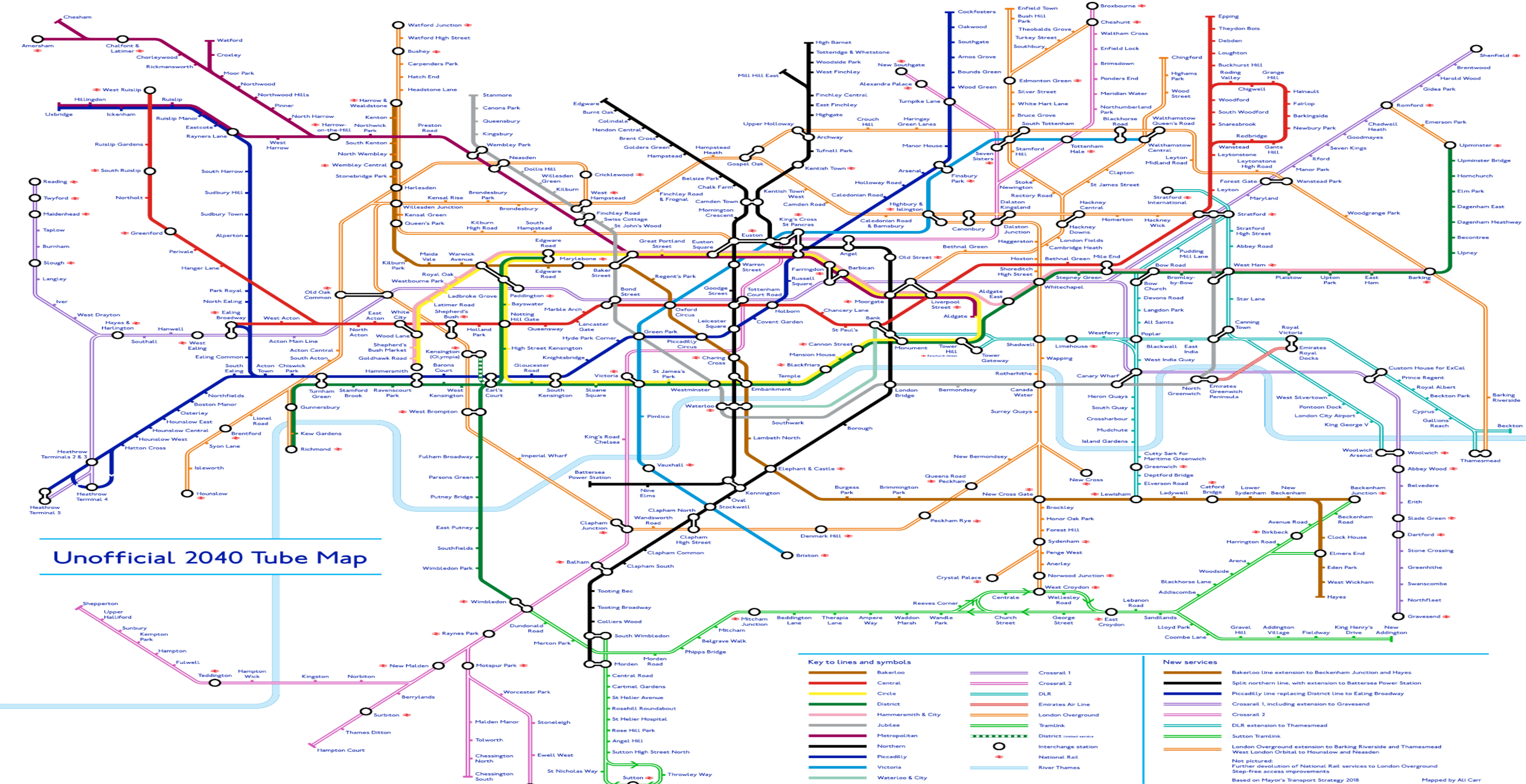
In your groups, discuss what we mean by a model.

What examples of models you have seen or used -
- In physics?
- In biology?
- In chemistry?

Why do we use models?



Here is an example model: What does it show? What are the pros and cons?



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How can BEST help you implement the recommendations of the EEF *Improving Secondary Science* report (2018)?

1 Preconceptions: Build on the ideas that pupils bring to lessons

How BEST can help:

Research summaries
Research findings on common preconceptions and misunderstandings explained clearly

Diagnostic questions
Quickly identify the preconceptions and misunderstandings students have

Response activities
Adaptive teaching to meet students' learning needs and build understanding

2 Self-regulation: Help pupils direct their own learning

How BEST can help:

Small-group discussion activities
Engage students in metacognitive dialogue

'Talking heads' activities
Encourage exploratory talk

Building explanations
Help students to link scientific ideas through sequencing activities and explanatory stories

3 Modelling: Use models to support understanding

How BEST can help:

Building understanding
Explicit use of models help to explain difficult ideas and make predictions

'Critiquing a representation' activities
Help students to think critically about scientific models by identifying their benefits and limitations

4 Memory: Support pupils to retain and retrieve knowledge

How BEST can help:

The 'big ideas' of science
Developed through key concepts

Key concepts
Focus learning to reduce cognitive load with appropriately-sequenced learning steps

Conceptual progression maps
Focus teaching in students' 'zone of proximal development'

5 Practical Work: Use practical work purposefully and as part of a learning sequence

How BEST can help:

Purposeful practical work
Practical activities focused on developing understanding and key competencies

'Predict-explain-observe-explain' activities
Challenge students to apply what they know

Cognitive conflict
Practical activities to challenge students' misunderstandings

6 Language of Science: Develop scientific vocabulary and support pupils to read and write about science

How BEST can help:

'Focused cloze' activities
Consolidate understanding of key scientific terms

'Re-phrasing' activities
Students encouraged to express scientific ideas in their own words

'Identifying evidence' activities
Challenge students to identify the key ideas in passages of scientific writing

7 Feedback: Use structured feedback to move on pupils' thinking

How BEST can help:

Progression toolkits
All that is needed for progression without levels, including:

Progression pathways
Research-Informed learning steps for each key concept

Diagnostic questions
Provide feedback from student to teacher, to help you decide what happens next

Response activities
Challenge misunderstandings and build scientific thinking

Commonly used models

Three dimensional models, for example a plastic ball-and-stick model of an organic molecule, a coloured plastic model of the human circulatory system

Verbal and written models, for example analogies such as the water flow analogy for electric current.

Mathematical models, for example equations of motion and chemical formulae.

Visuals such as graphs, diagrams, and animations

Computer models e.g. simulations of population growth.

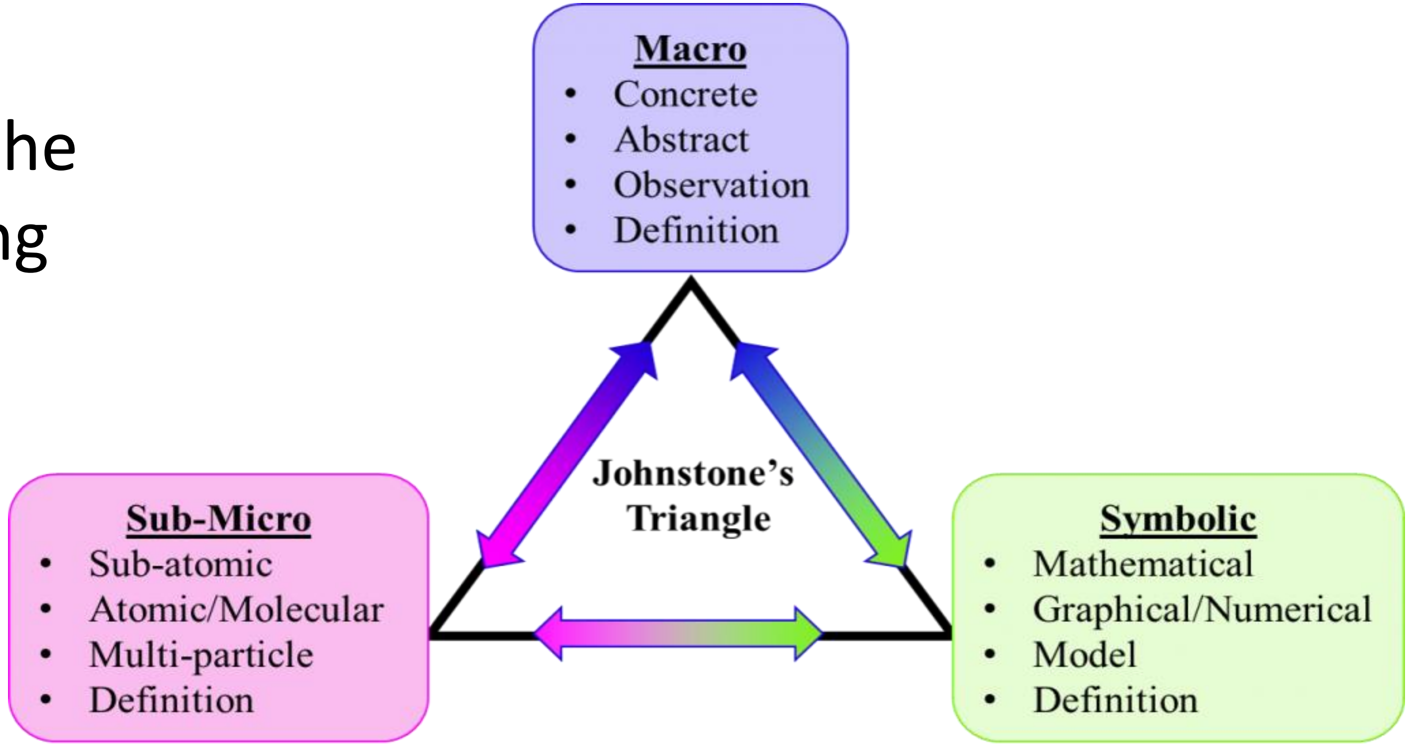
Johnstone’s triangle

- Chemistry education model showing chemical knowledge on three interconnected levels.
  - **Macroscopic:** phenomena that you can observe directly, e.g. identifying chemical changes in everyday life, such as cooking, rusting of metals, or combustion.
  - **Submicroscopic: c**oncepts that are too small to see, e.g. molecules, structures, geometry, polarity.
  - **Symbolic:** chemical symbols, formula/equations, diagrams, hazard warning symbols.

- **Improve students’ understanding with Johnstone’s triangle | Feature | RSC Education**

Linking between levels of description

Repeatedly building and reinforcing links between the levels is better than working between all three at once.



Johnstone, 1982

What the research says

Johnstone A. H., (1991), Why is science difficult to learn? Things are seldom what they seem J. Comput. Assist. Learn., 7, 75–83.

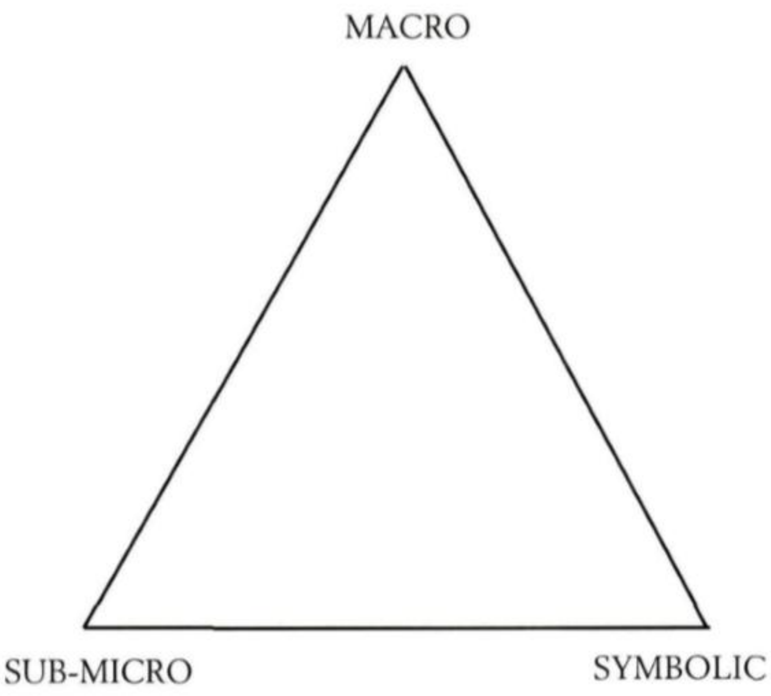


***Figure 1** Three levels of thought.*

Educational implications

The teacher, as an expert, has the facility to flit intellectually from corner to corner of the triangle (figure 1), and even to operate within the triangle where thoughts can comprise all three components simultaneously and in differing proportions. This is not an intellectual facility shared by novices. To begin with, they operate at one level (or corner) at a time and then progress to thinking along one side, combining two corners. It is a long time before they can follow the teacher into the body of the triangle.

It may be that the solution to the learning problems in genetics is to develop this thinking slowly, coming back to it many times and controlling the complexity by operating on the sides of the triangle only. This will need time to develop experimental experience of the MACRO, careful control of vocabulary and concepts in the SUBMICRO and phased introduction of the SYMBOLISM.

When the analogy breaks down: modelling the atom on the solar system

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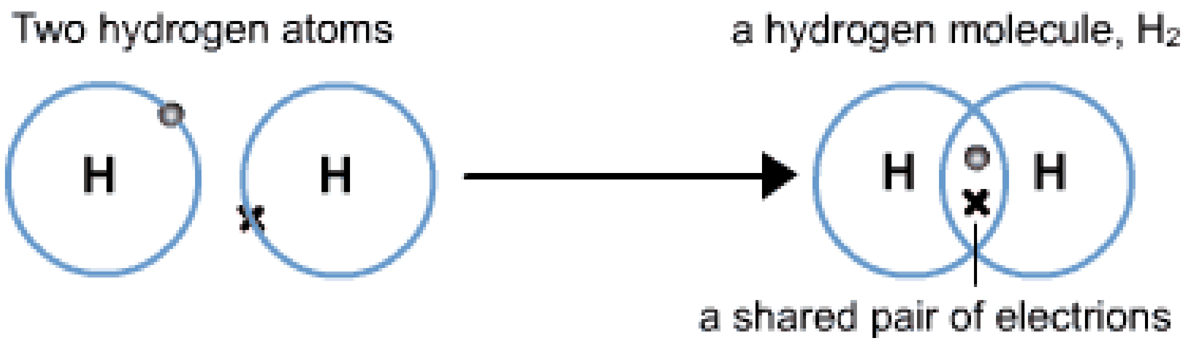
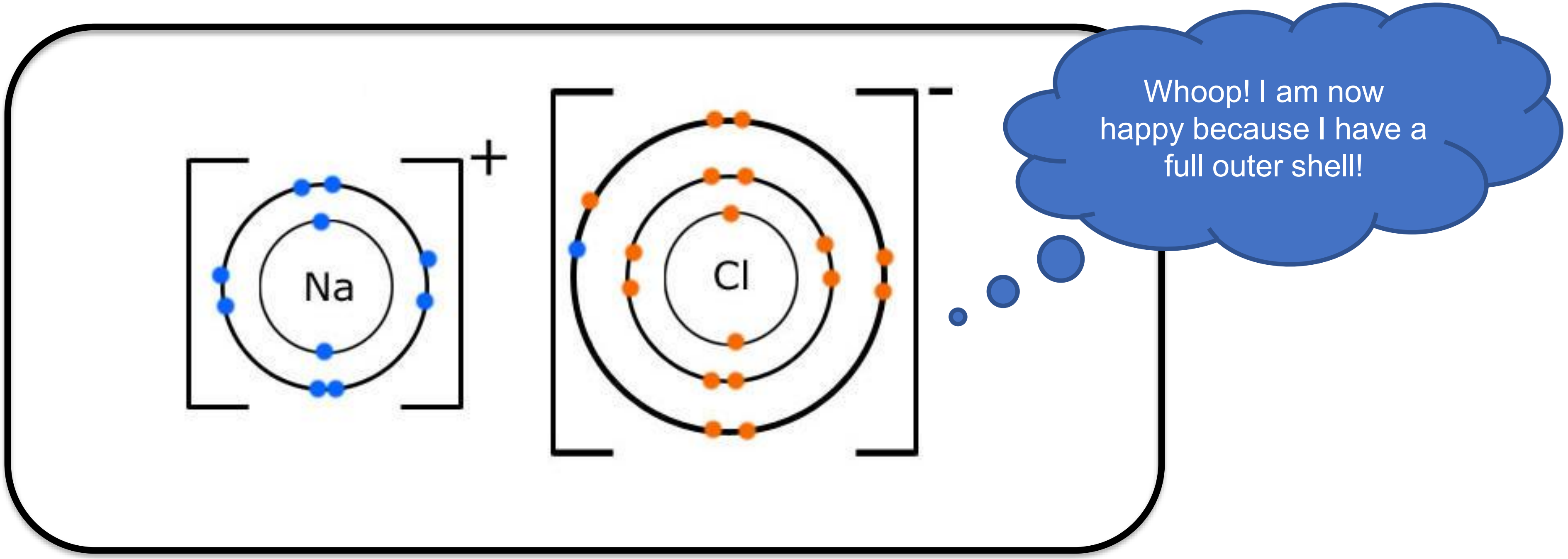
Abstract
Analogy is one of the most potent tools in the teacher's repertoire, and has been recognized as a common feature of science teaching. It is also accepted, however, that teaching effectively using analogy requires careful planning. It is important to emphasize the limitations of the analogies used in explaining scientific ideas. This article also highlights another potential difficulty: when the analogue is not as familiar to learners as the teacher may assume.

What are the advantages and disadvantages of these models?





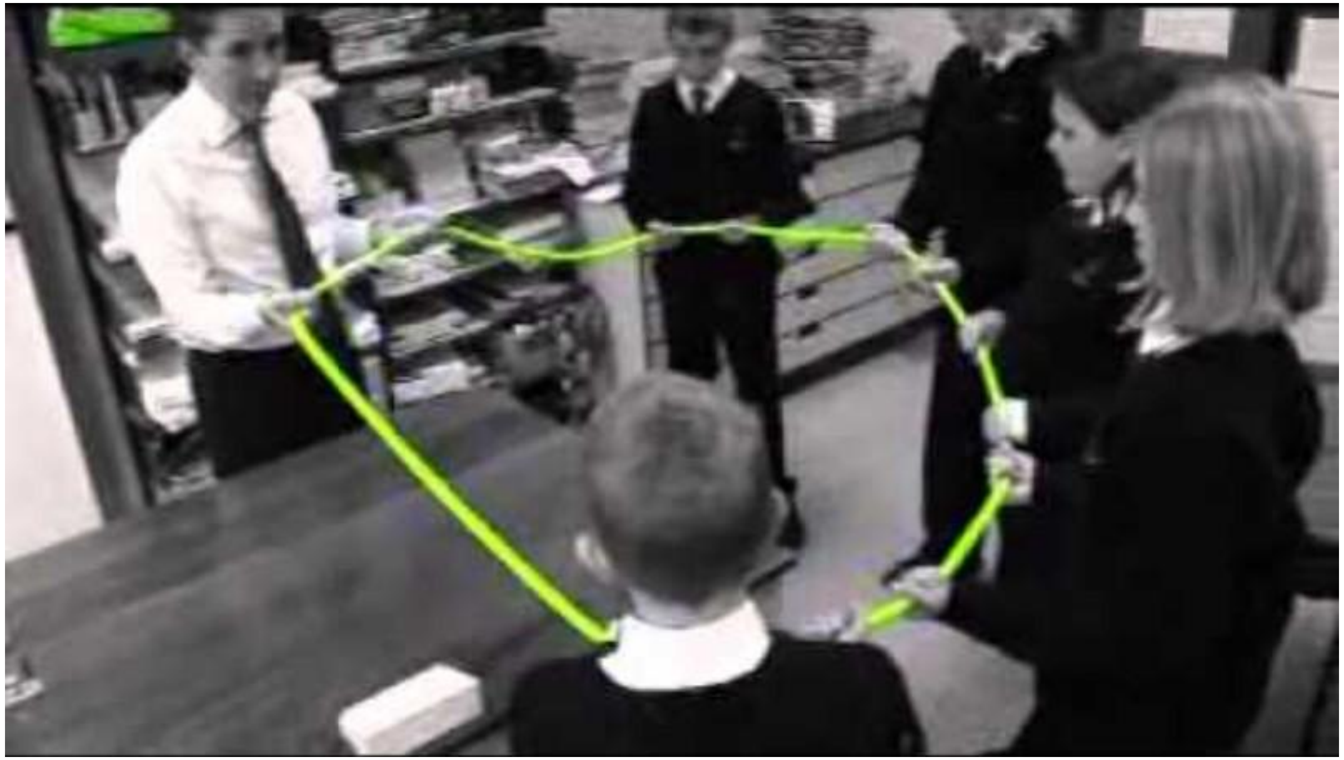
Taber K.S. (2006) Beyond Constructivism: the Progressive Research Programme into Learning Science. *Studies in science education,* **42**(1) pp.125-18

Points to consider when teaching models

Teach students about models and get them thinking critically about their use

- Teach students explicitly why we use models.
- Discuss the strengths and weaknesses of the models you are using.
- Use a number of different model types when teaching an idea.
- Help students to see the links between phenomena that they experience, models that make sense of these experiences, and symbolic representations of phenomena.
- Encourage students to develop their own models and share them with you and with their peers.

Electric circuit models



Using models effectively in teaching – FAR approach

Focus

Concept – is it difficult, unfamiliar or abstract?

Students – what ideas do the students already have about the concept?

Analogue – is it something students are already familiar with?

Action

Likes – discuss the features of the analogue and the science concept.

- draw similarities between the analogue and target.

Unlikes – discuss where the analogue is unlike the science concept.

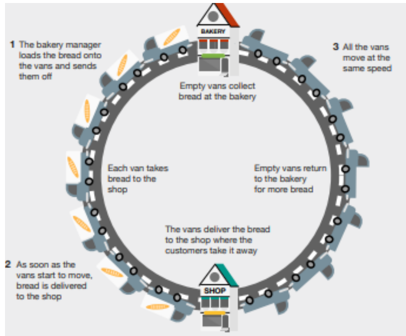
Reflection

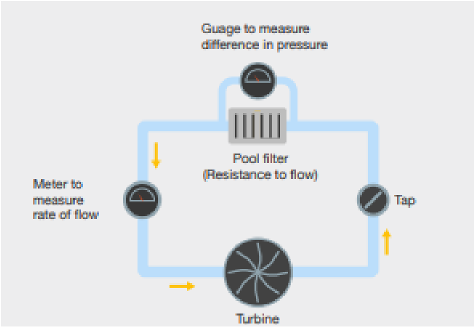
Conclusions – was the analogy clear and useful, or confusing?

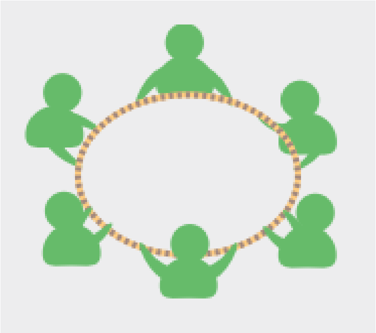
Improvements – refocus as above in light of outcomes.

USEFUL RESOURCES FROM THE ROYAL SOCIETY OF CHEMISTRY

https://edu.rsc.org/feature/reflect-on-your-use-of-models/3010509.article







Apply the focus and action sections of the FAR tool to a model in your subject discipline

What models could you use to explain:

- the relative size/spacing of the planets
- kinetic theory (conduction or diffusion etc)
- covalent bonding
- differences between alpha, beta and gamma radiation
- atomic structure
- different types of waves (longitudinal and transverse)
- exponential growth

Box 8: The FAR approach to using models

Focus (before lesson)	
Concept that will be taught during the lesson	Is it a difficult, unfamiliar, or abstract concept or process?
Pupils	What ideas do pupils already know about the concept or process that the model will be describing?
Model	Is the model itself something that pupils are familiar with? (For example, if using water flow to model electric current, do pupils know about turbines and water pumps?).
Action (during lesson)	
Discuss	Discuss the features of the science concept and the model.
Likes	Draw similarities between the concept and the model.
Unlikes	Discuss where the model is different from the concept.
Reflection (after lesson)	
Conclusions	Was the model clear and useful, or confusing?
Improvements	How could the model be improved for future use? Do the class need to revisit the idea?

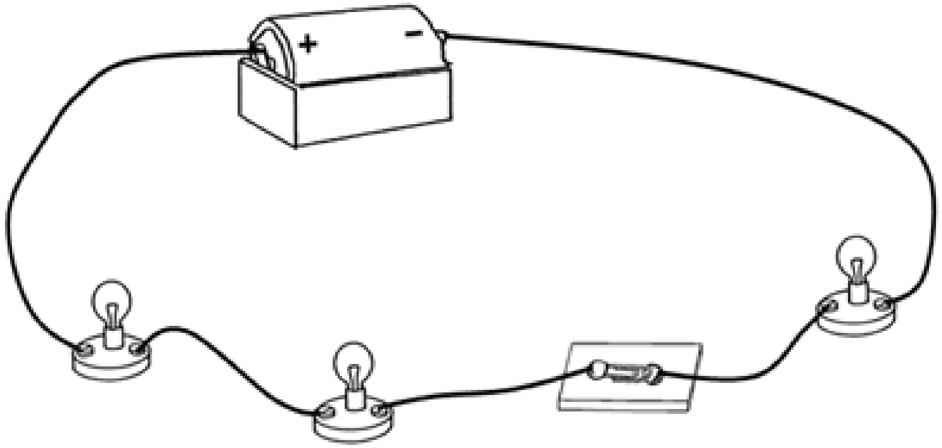
Adapted from Treagust et al., 1998[31]

An example assessment in physics

Flow

Some students are talking about electric charge.

They are thinking about how it moves round a circuit.



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Where have students got confused?

Flow

1. Who thinks that something flows around the circuit when it is turned on?
2. Who did not quite understand how electric charge flows? What would you say to them to help them to understand?

Ali
If charge flows out of the battery it will go round the circuit. The bulbs will light up one after the other.

Bella
The charge is already in the wires. When the battery is connected, all the charge starts flowing. This explains why the bulbs all light up straight away.

Dan
If something was flowing, it would leak out when you opened the switch. It would be like water coming out of a broken pipe.

Chloe
Charge stays in the wires. If there is a break in a wire it blocks the flow and all the charge stops moving. All the bulbs go out at once.

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